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FLAMMABILITY TESTS ON RUBBER AND PVC CONVEYOR BELTING

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by

K.J. Mintz*

ABSTRACT

Oxygen index tests and hot plate ignition tests were carried out on 11 rubber belts, both fire-resistant and non-fire-resistant types, and three PVC fire-resistant belts. The oxygen index tests distinguished between the fire and non-fire-resistant belts. The fire-resistant rubber belts made to MSHA quality yielded ignition temperatures similar to the non-fire-resistant belts, and much lower than the PVC belts made to NCB quality. A slight correlation was found between the thickness of the belt (or number of plies) and its flammability (as measured by both tests): the thicker, the more flammable.

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MESURE DE L'INFLAMMABILITÉ DE COURROIES TRANSPORTEUSES EN CAOUTCHOUC ET EN PVC

par

K.J. Mintz*

RÉSUMÉ

Des essais d'indice d'oxygène et des essais sur surface chaude visant à déterminer le point d'inflammabilité ont été effectués sur 11 courroies en caoutchouc des deux types, soit ininflammable et inflammable, et sur trois courroies ininflammables en PVC. Les essais d'indice d'oxygène ont permis de déterminer les courroies résistantes au feu. Pour les courroies en caoutchouc ignifuge fabriquées selon les normes de la MSHA on a enregistré des points d'inflammabilité qui correspondent à ceux des courroies inflammables et sont beaucoup moins élevés que ceux des courroies en PVC fabriquées selon les normes de la NCB. On s'est rendu compte qu'il existe un faible lien entre l'épaisseur d'une courroie (c.-à-d. le nombre de plis) et son inflammabilité (telle que mesurée au cours des deux essais susmentionnés): plus une courroie est épaisse, plus elle s'enflamme facilement.

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INTRODUCTION

Although the principle that conveyor belts used in underground mines must be "fire-resistant" is widely accepted, there is no general agreement on the most appropriate test methods. The most straightforward method is to apply a given amount of heat to a full-size belt, determine whether it ignites and whether the flame propagates. By its very nature, such a full scale test requires costly facilities. Moreover, it is difficult without unlimited resources to vary all the parameters so as to establish that the results obtained under the particular experimental conditions can be universally applied.

Hence, valid small-scale tests can be useful in establishing what parameters affect the fire-resistancy of the conveyor belts. To do that, the tests must be quantitative, rather than just pass/fail. The current flame test used at the Canadian Explosive Atmospheres Laboratory (CEAL) for certification could in principle be adapted to a quantitative approach (the parameter would be the number of seconds for the flame to be extinguished). However, the scatter of values on samples of the same material is much too large.

Studies at CEAL have shown that the current sampling method for both the EMR and the National Coal Board (UK) tests can lead to both false passes and false failures, just because of the large scatter. It was suggested that sufficient samples be tested to use a statistical approach, specifically, to fit the data to the Weibull equation. Although that approach has some merit (and should be used if the current EMR test is retained), the fact that there is a large scatter indicates that there are underlying unknown parameters in that test. Alternative test methods which have less scatter would be more desirable.

Two other small-scale tests are currently being evaluated as replacements: the oxygen-index test (1) and the hot-plate ignition test (2). Samples of an extended series of rubber conveyor belts of various thicknesses and plies have been examined for correlations. The purposes of the investigation were to determine: (a) whether there is a distinct difference in ignition temperature between belts that pass the propane gallery test (NCB quality) and those that do not (MSHA quality); and (b) whether the thickness of the rubber covers and the overall thickness affect the ignition temperature.

EXPERIMENTAL METHODS

The oxygen index tests were carried out as in Ref. 1. The sample size was 25 mm wide by the full thickness.

The hot-plate tests used samples of 25 mm square. The samples were placed on a type 310 stainless steel plate, 25 mm thick, which had been heated in a muffle furnace. The time to ignition at various temperatures was recorded. Details of the method are in Ref. 2.

RESULTS AND DISCUSSION

HOT-PLATE IGNITION TEST

The graphs of ignition time vs ignition temperature for each belt are shown in Fig. 1-20. As can be seen, there is some random scatter. Two or three runs are required to establish the curve with some degree of precision. Many of the curves show a distinct plateau. Although some of the graphs could be drawn as a continuous curve rather than with a plateau, we have amassed sufficient evidence to prove that a plateau exists. Earlier we had postulated that the plateaux were related to the time required for the heat to penetrate to the carcass. However, if that were true, the location (in time) of the plateaux should be a strong function of the cover thickness. That does not appear to be so. At present, we can only suggest that there is more than one mechanism for ignition. It should be noted that the samples that do not ignite have nearly completed combusting by 120 s, i.e., if they do not burst into flames by that time, they will never do so. This test is concerned with the tendency of a surface to ignite. This process either occurs or does not occur within a few seconds. Somewhat arbitrarily, 10 s has been chosen to be the cutoff time. The experimental uncertainties associated with this method make the precision ca. ±10°C.

The ignition temperatures obtained in this way are shown in Table 1. For the non flame-resistant (general purpose) belts, the values range from 672 to 710°C. Although that difference indicates that there are real differences in fire-resistancy amongst these belts, the range is not great enough to identify specific parameters. Assuming that the chemical compositions of all the general purpose belts are identical, then certain trends seem to be indicated:

1. The ignition temperature decreases with increasing number of plies (Fig. 21).
2. The ignition temperature decreases with increasing total thickness (Fig. 22). The thickness is, of course, related to the number of plies; however, the slope is steeper and the coefficient of correlation (r^2) higher with the latter.
3. There is no correlation (r^2 = 0.004) between ignition temperature and cover thickness (Fig. 23).
4. In spite of the above, five of the six asymmetrical belts had a lower ignition temperature on the thinner side; the sixth had the same ignition temperature on both sides. The greatest differences were the ones involving the thinnest covers (0.8 mm), which seems reasonable.

Instead of defining the ignition temperature as the temperature corresponding to the 10 second ignition time, one can define it as the maximum temperature at which no flaming combustion occurs. The values obtained in this way are also shown in Table 1. They are much more approximate than the "10 second" values. Hence, the trends discussed above are not as clear, but there are no contradictions.

OXYGEN INDEX TESTS

The oxygen index of the non fire-resistant belts range from 23.1 to 25.1 (see Table 1). This range is much greater than the experimental precision, thus there are real differences in oxygen index. Figure 24 shows that there is some correlation between the oxygen index and the ignition temperature, but it is not perfect, even allowing for the experimental uncertainties. As with the ignition temperature the oxygen index correlates somewhat with the number of plies and the total thickness, decreasing (i.e., less fire-resistant) with increasing thickness.

FIRE-RESISTANT RUBBER BELTS

The surface ignition temperatures of two of these belts are in the middle of the range of the non-fire resistant belts. The third one is slightly higher, but still much less than fire-resistant belts made to MCB quality. On the other hand, the oxygen index values are well above those of the non-fire-resistant belts, being in the range of MCB quality belts.

PVC BELTS

Three fire-resistant belts have been tested with the results shown in Table 2. The superiority of Belt B comes out clearly in both the oxygen index and the hot plate ignition test. This belt is also the first one tested to show a marked difference in oxygen index between samples cut in the transverse and longitudinal directions. This difference may be due to a difference in char formation. Belt B produces much more char than the other belts particularly for samples cut in the transverse direction, perhaps causing its better performance.

The effect of sample width on the oxygen index is shown in Table 3. There are two plateaux, one below 10 mm and the other above 15 mm, with a steep rise between. The "standard" sample width used in this study (25 mm) was selected to be in the middle of the upper plateau.

The PVC belts, made to NCB quality, have distinctly higher ignition temperatures than the rubber belts made to MSHA quality. From the viewpoint of correlating the hot plate test with the propane gallery test, these results are indeed encouraging.

The oxygen index does not differentiate between NCB quality and MSHA quality belts. It does differentiate well between non-fire-resistant and fire-resistant to MSHA standards.

However, it must be pointed out that the propane gallery test in its present form is very dependent on the thickness of the sample. Until the parameters affecting the propane gallery test are better understood, it would be premature to make a definitive statement on its correlation with a small-scale test.

CONCLUSIONS

1. Both the hot plate ignition test and the oxygen index test give reasonably reproducible results. However, they measure different properties.
2. According to the hot plate ignition test, the MSHA-approved fire-resistant rubber belts are no more ignition-resistant than the non fire-resistant belts.
3. The oxygen index test distinguishes between belts that are classified by MSHA as fire-resistant and those that are non fire-resistant.

REFERENCES

1. K.J. Mintz "Procedure for oxygen - index tests at CEAL"; Division Report ERP/MRL 83-46(TR).

2. K.J. Mintz, J.A. Bossert and M.S. Ralph, "The hot-plate ignition test, a proposed new test for fire-resistant conveyor belts"; Division Report ERP/MRL 83-70(TR).

Table 1 - Rubber conveyor belts: oxygen index and hot plate ignition tests

Construction	Service†	Thickness (mm)		O.I.	Ignition temp (°C)**	
		total	covers	(% O_2)	10 sec	∞
1-ply	GP	4.3	1.2 x 1.2	25.1	710	660
1-ply	GP	7.1	3.2 x 3.2	24.7	704	660
2-ply	GP	4.6	0.8 x 0.8	24.0	696	650
2-ply	GP	7.4	3.2 x 0.8	24.3	710/688	640/650
2-ply	GP	7.1	3.2 x 0.8	24.6	702/688	660/630
2-ply	GP	9.7	4.8 x 1.6	24.4	684/686	- /660
2-ply	FR	6.4	1.2 x 1.2	28.4	694	620
3-ply	FR	8.1	1.6 x 1.6	27.3	736	690
3-ply	FR	12.7	6.4 x 1.6	28.6	702/692	680/660
4-ply	GP	14.2	6.4 x 1.6	23.9	682/672	650/640
4-ply	GP	23.1	12.1 x 3.2	23.1	692/680	650/670

† GP = general purpose; FR = flame resistant

** For asymmetric belts, the first number refers to the thicker side being in contact with the plate

∞ The number given is the highest temperature at which flaming combustion does not occur

Table 2 - PVC belts

Belting	Oxygen index (% O_2) transverse	longitudinal	Ignition Temp (°C) 10 sec	-
Type A	29.4	-	766	700
Type B	31.4	29.9	808	730
Type C	28.1	27.7	762	710

Table 3 - Effect of sample width on the oxygen index of PVC Type A conveyor belt

Width (mm)	Oxygen index
3	27.5
5	27.6
10	27.9
15	29.1
25	29.4
50	28.9

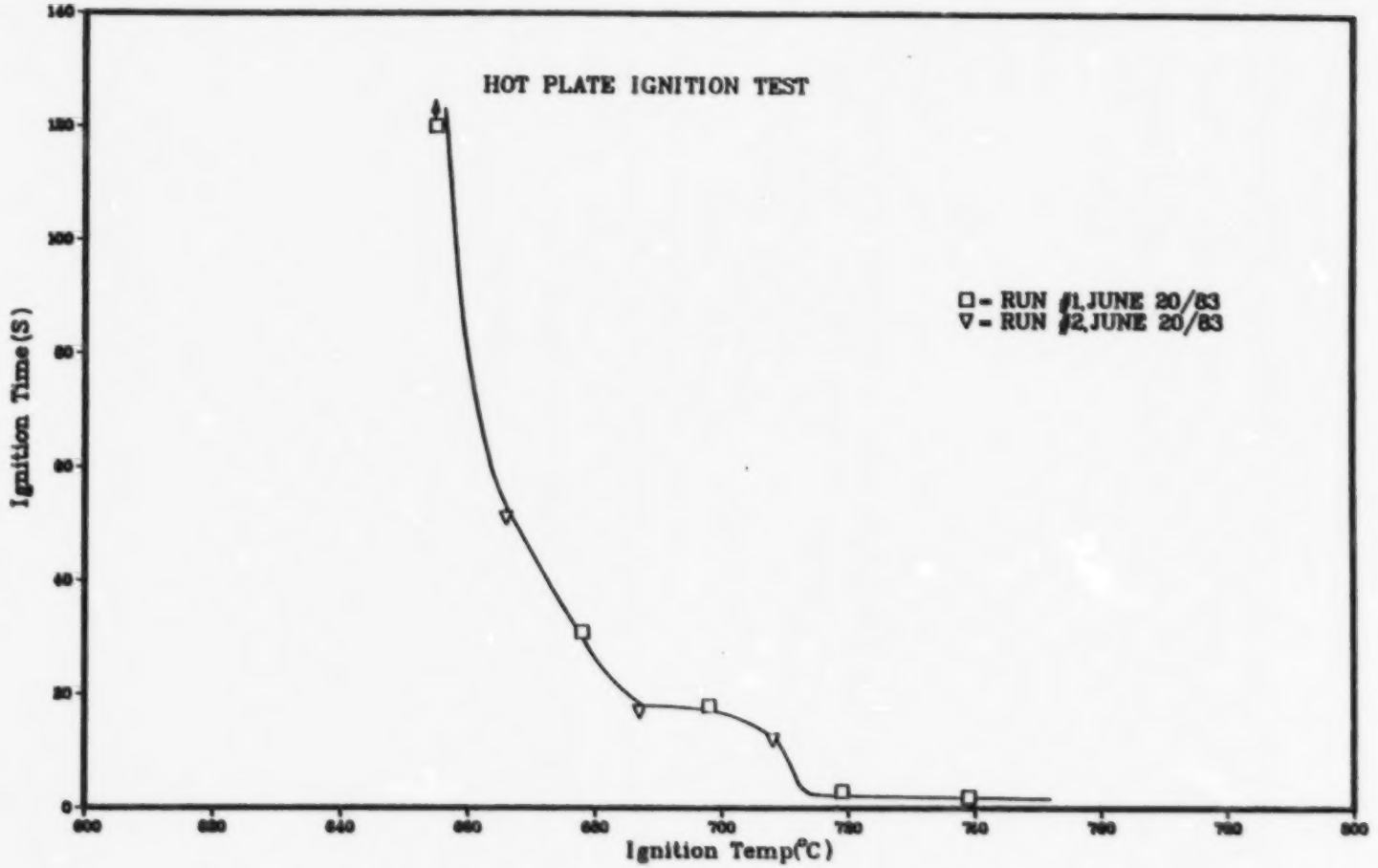

Fig. 1 - 1-ply G.P. - 1.2 x 1.2 mm

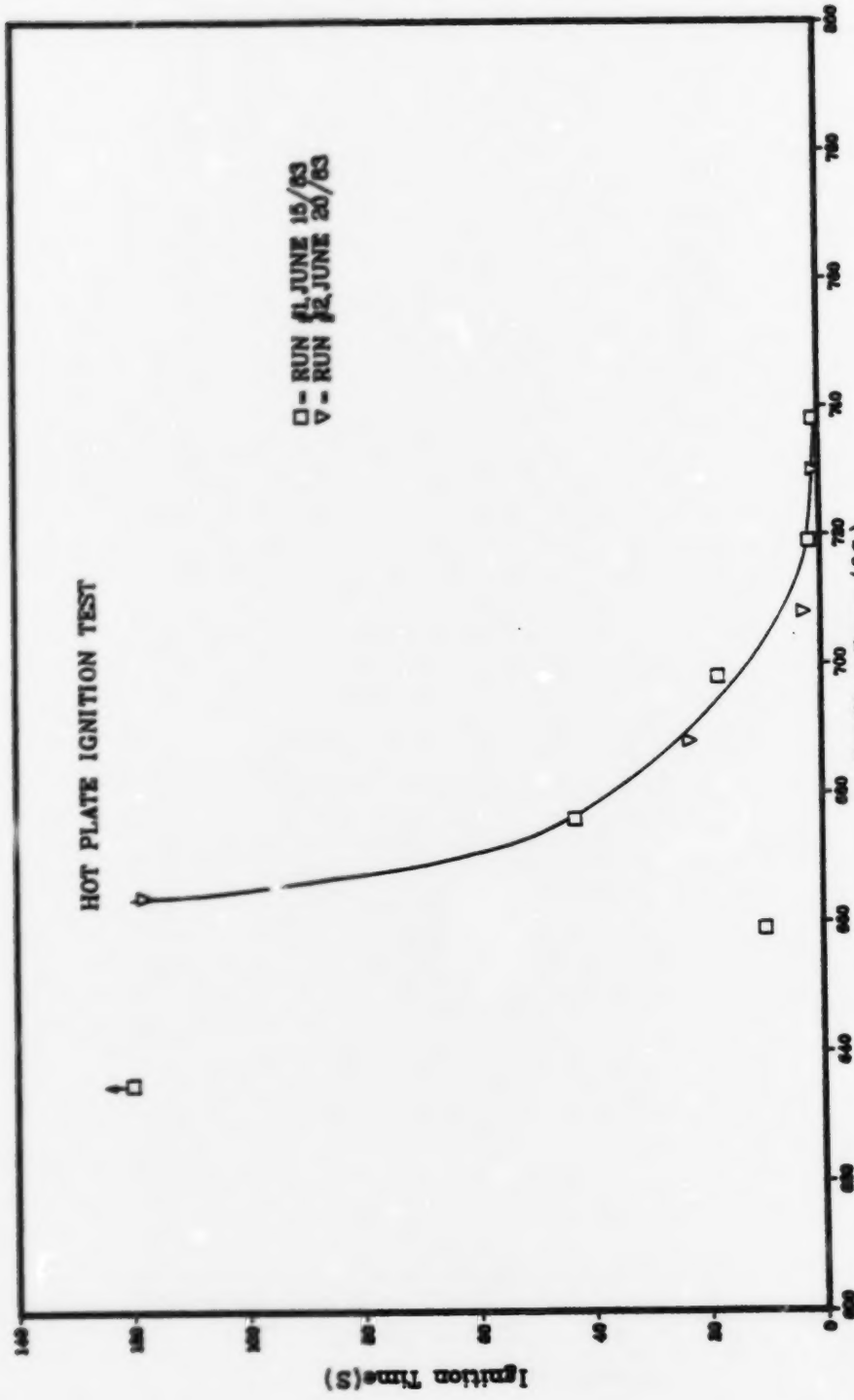

Fig. 2 - 1-ply G.P. - 3.2 x 3.2 mm

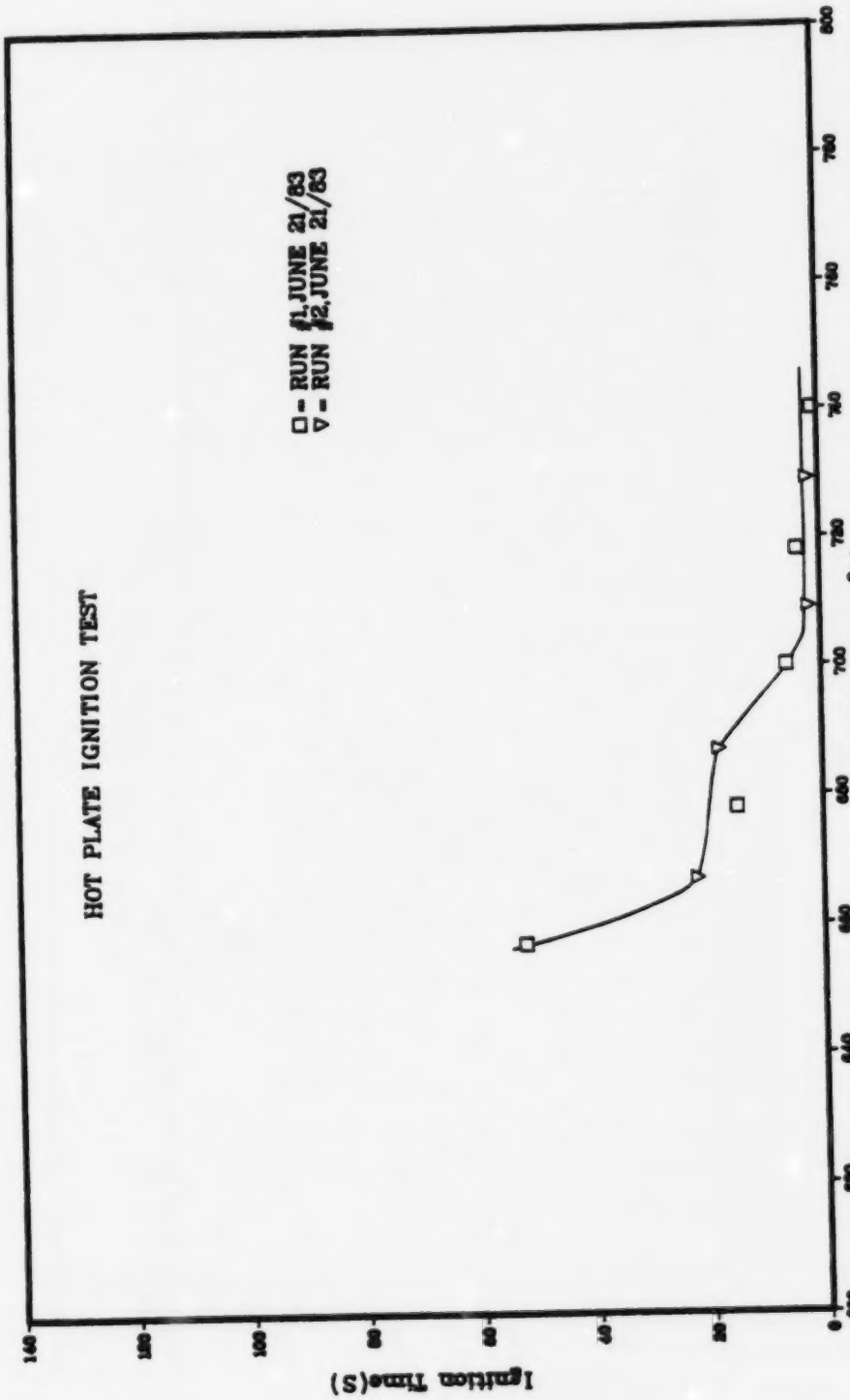

Fig. 3 - 2-ply G.P. - 0.8 x 0.8 mm

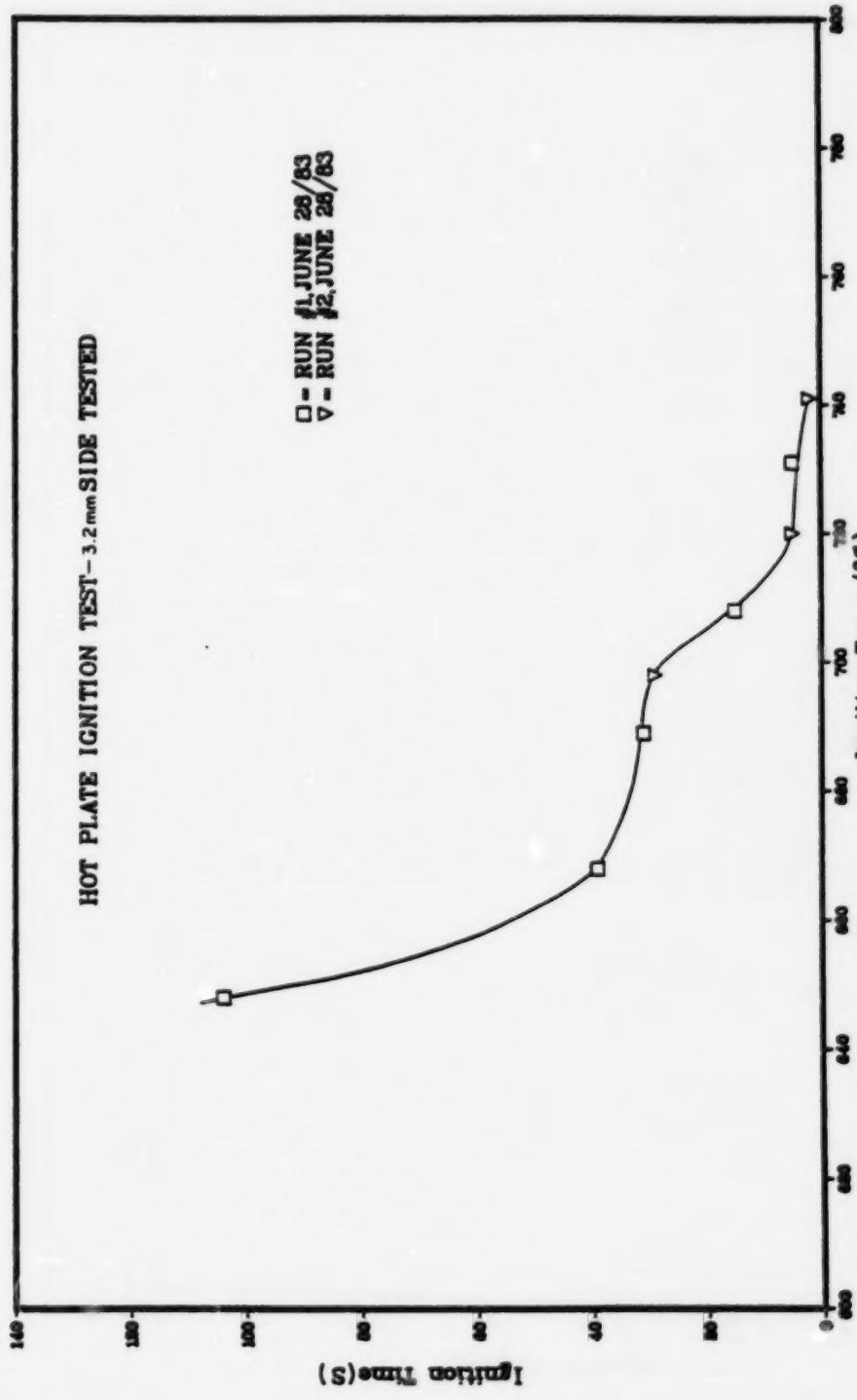

Fig. 4 - 2-ply G.P. - 3.2 x 0.8 mm

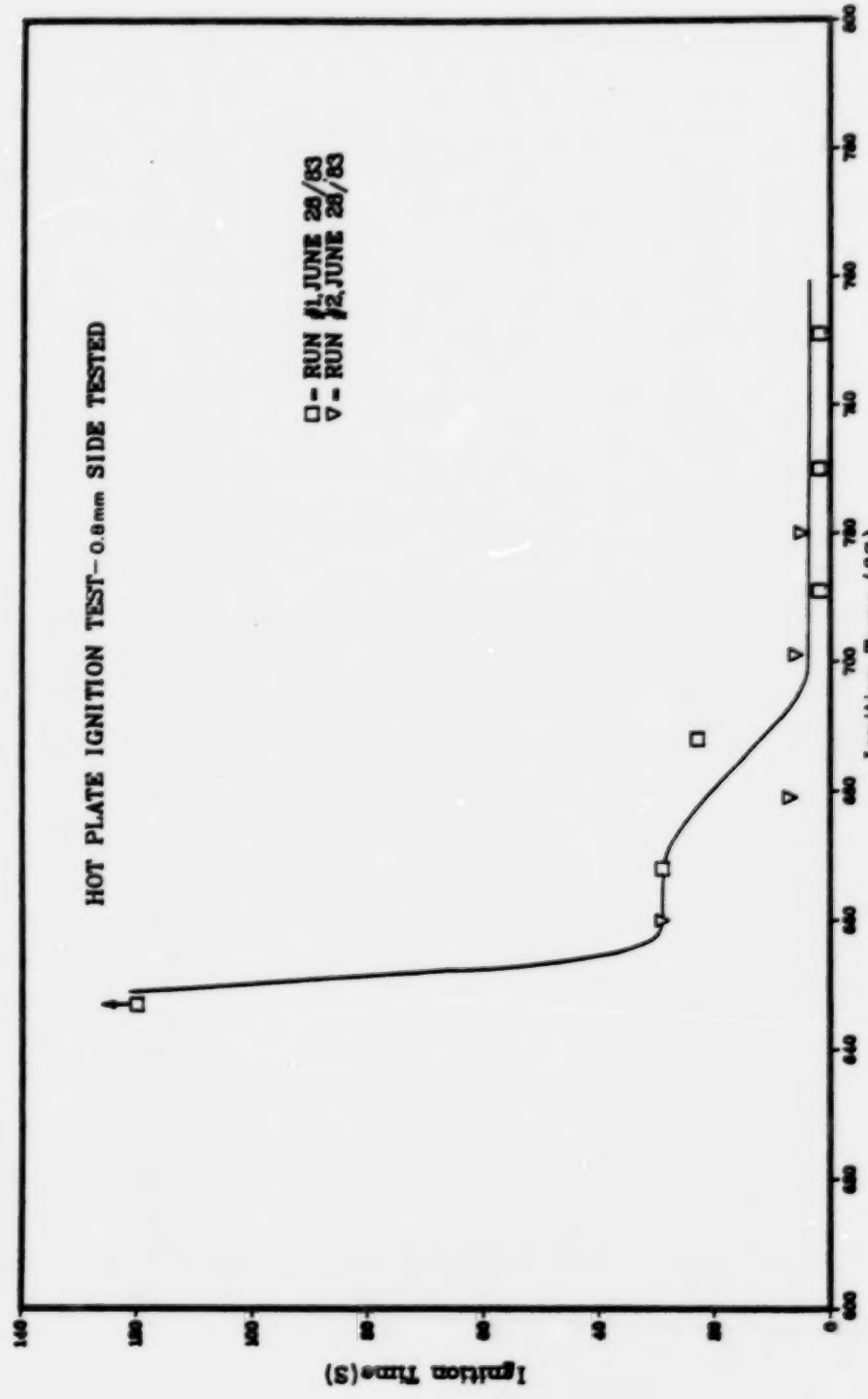

Fig. 5 - 2-ply G.P. - 3.2 x 0.8 mm

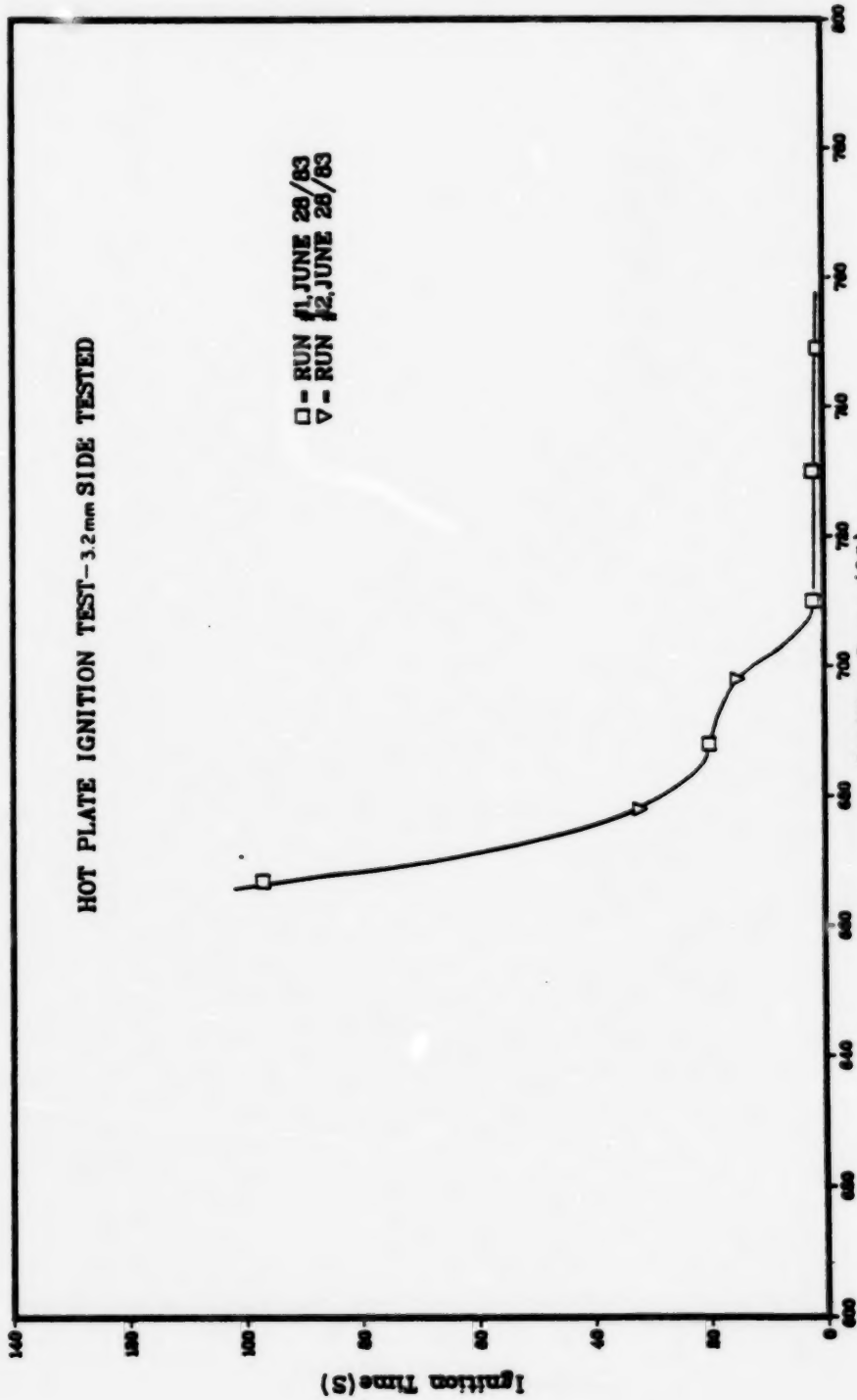

Fig. 6 - 2-ply G.P. - 3.2 x 0.8 mm

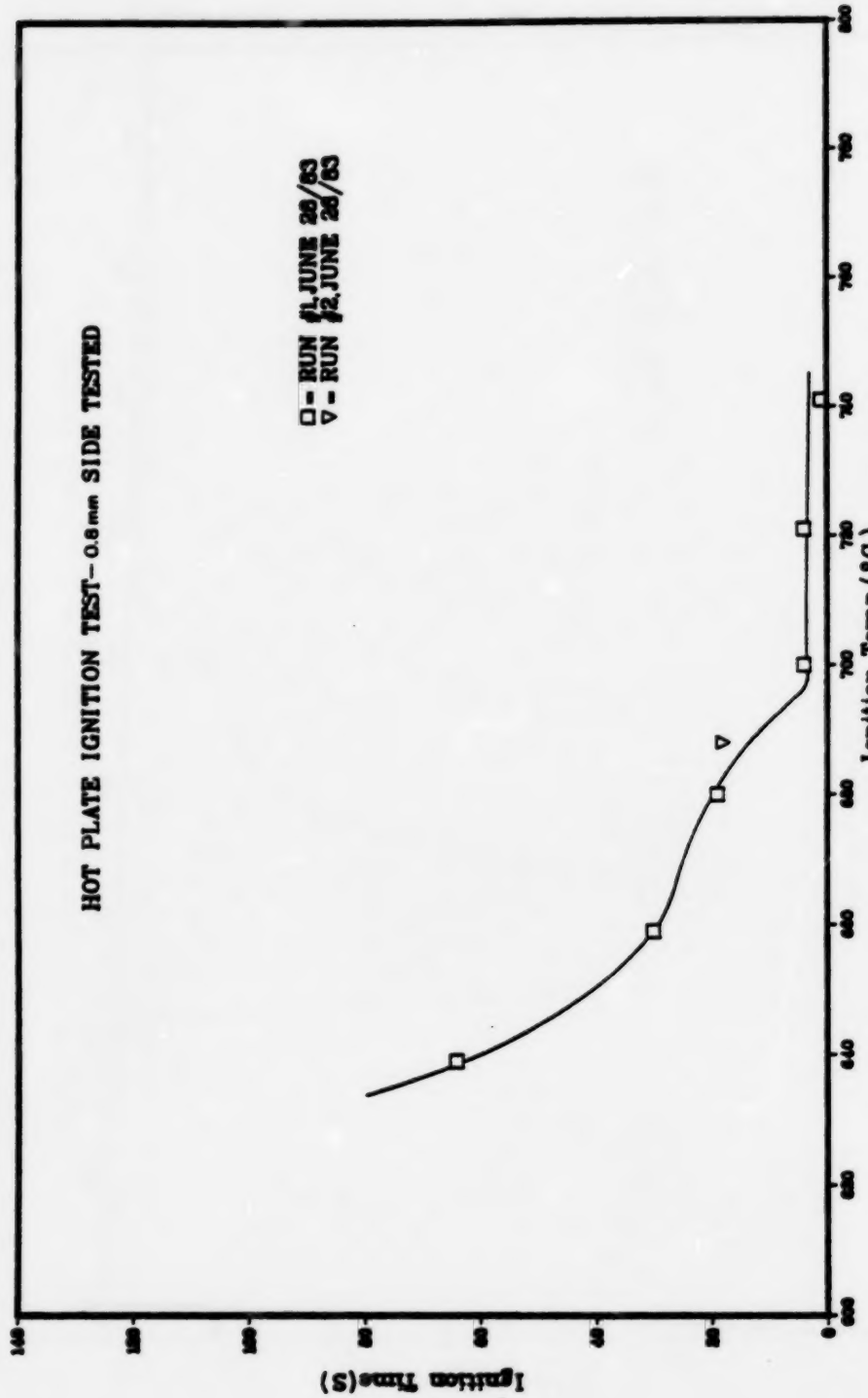

Fig. 7 - 2-ply G.P. - 3.2 x 0.8 mm

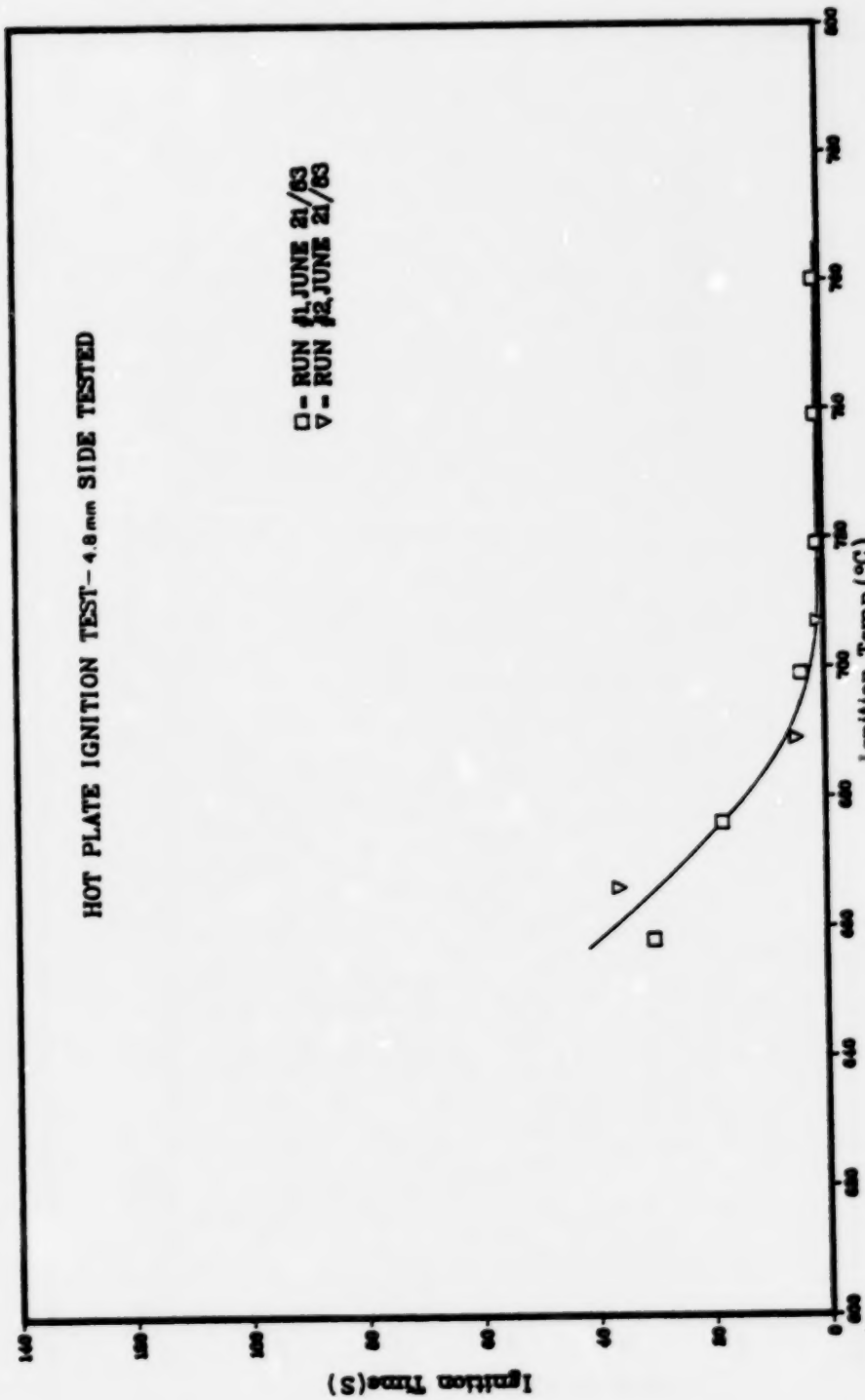

Fig. 8 - 2-ply G.P. - 4.8 x 1.6 mm

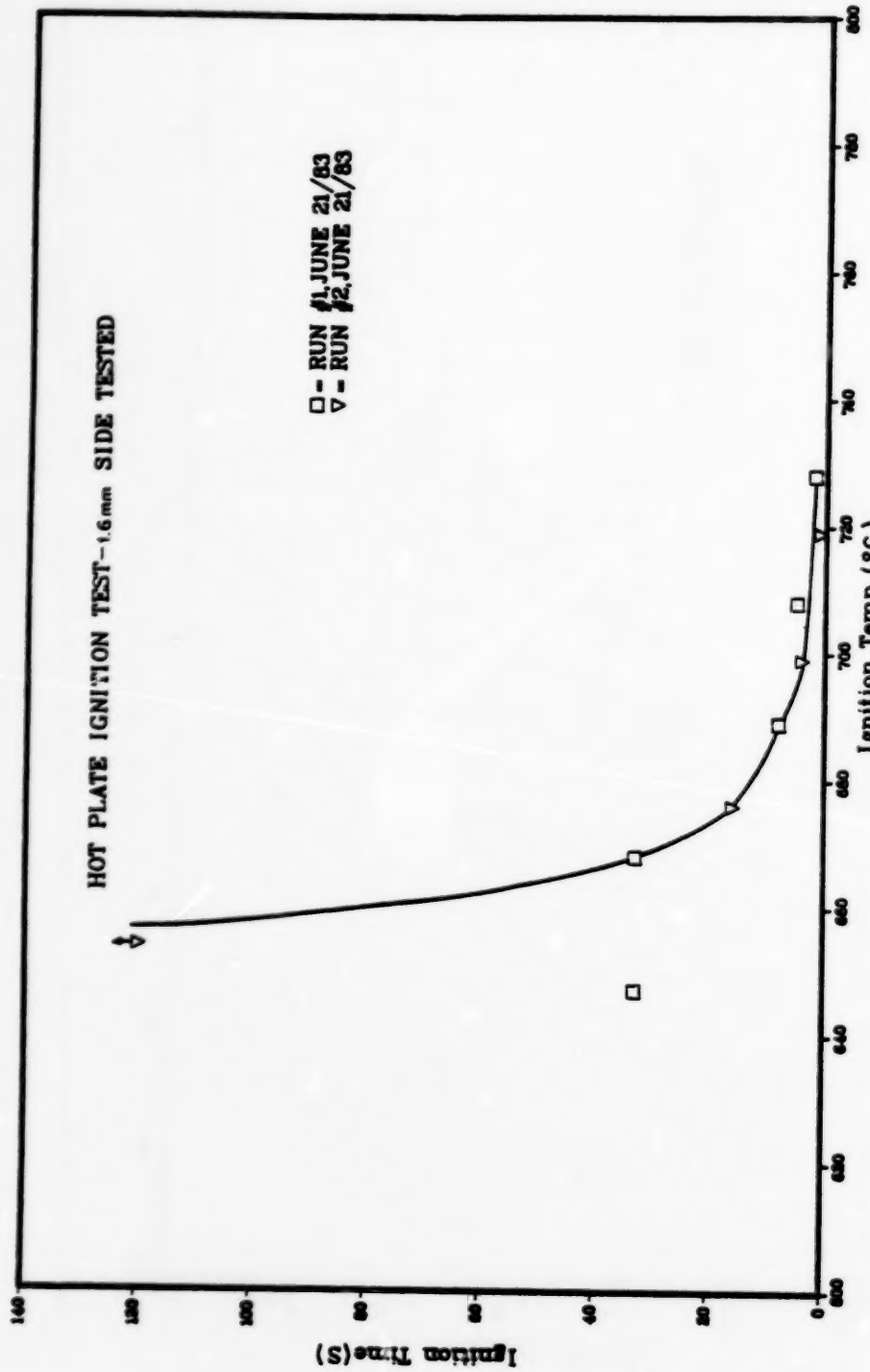

Fig. 9 - 2-ply G.P. - 4.8 x 1.6 mm

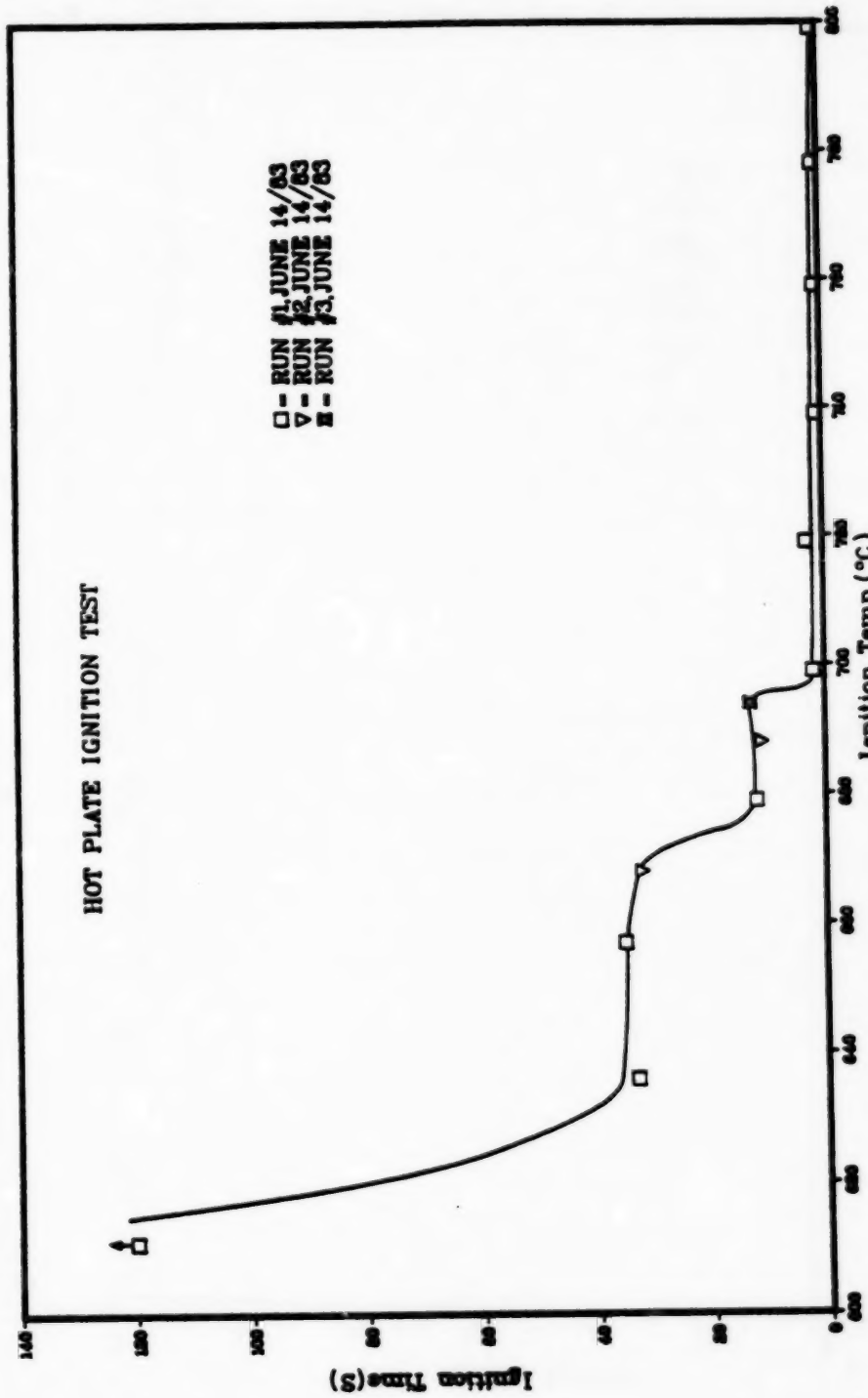

Fig. 10 - 2-ply F.R. - 1.2 x 1.2 mm

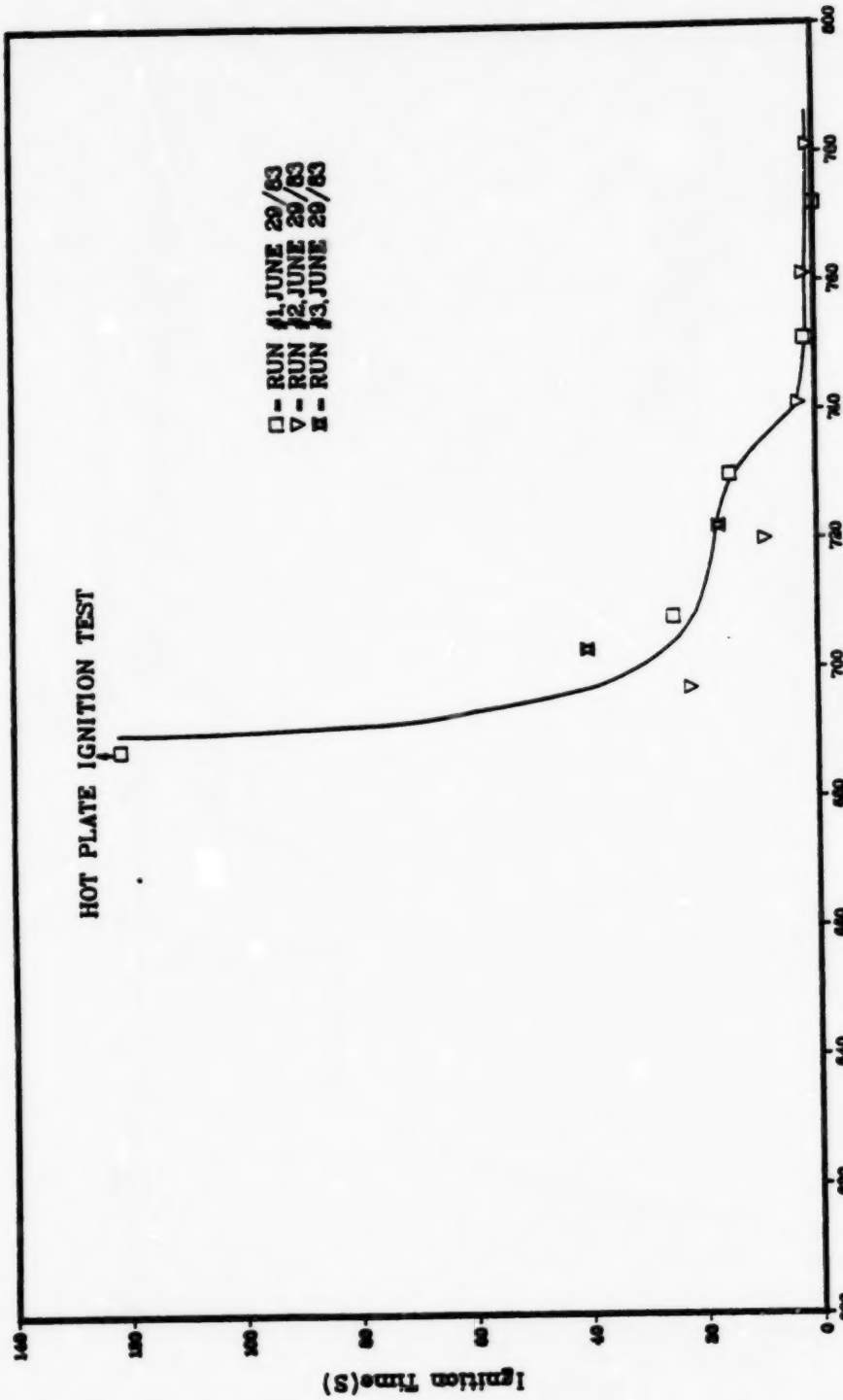

Fig. 11 - 3-ply F.R. - 1.6 x 1.6 mm

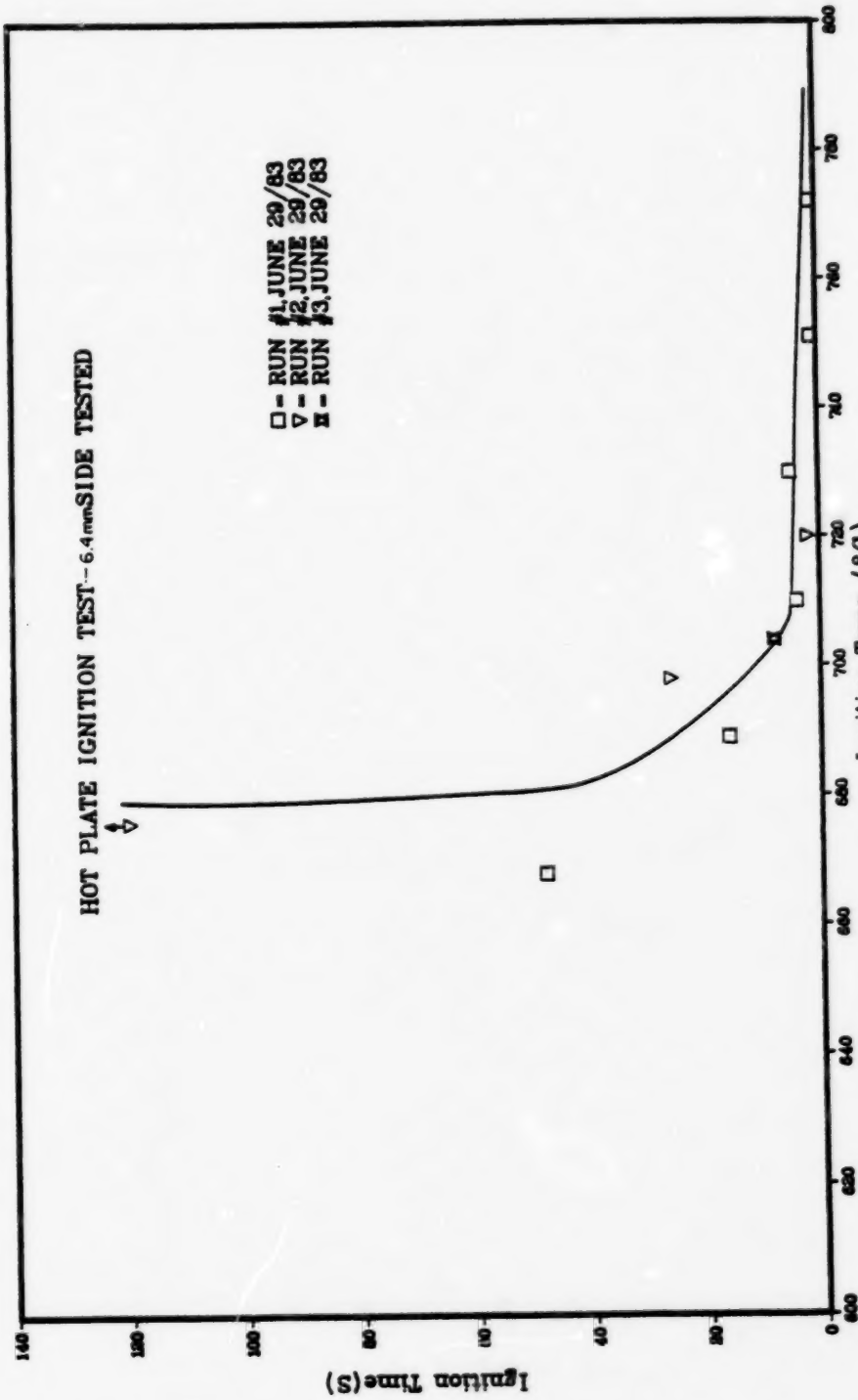

Fig. 12 - 3-ply F.R. - 6.4 x 1.6 mm

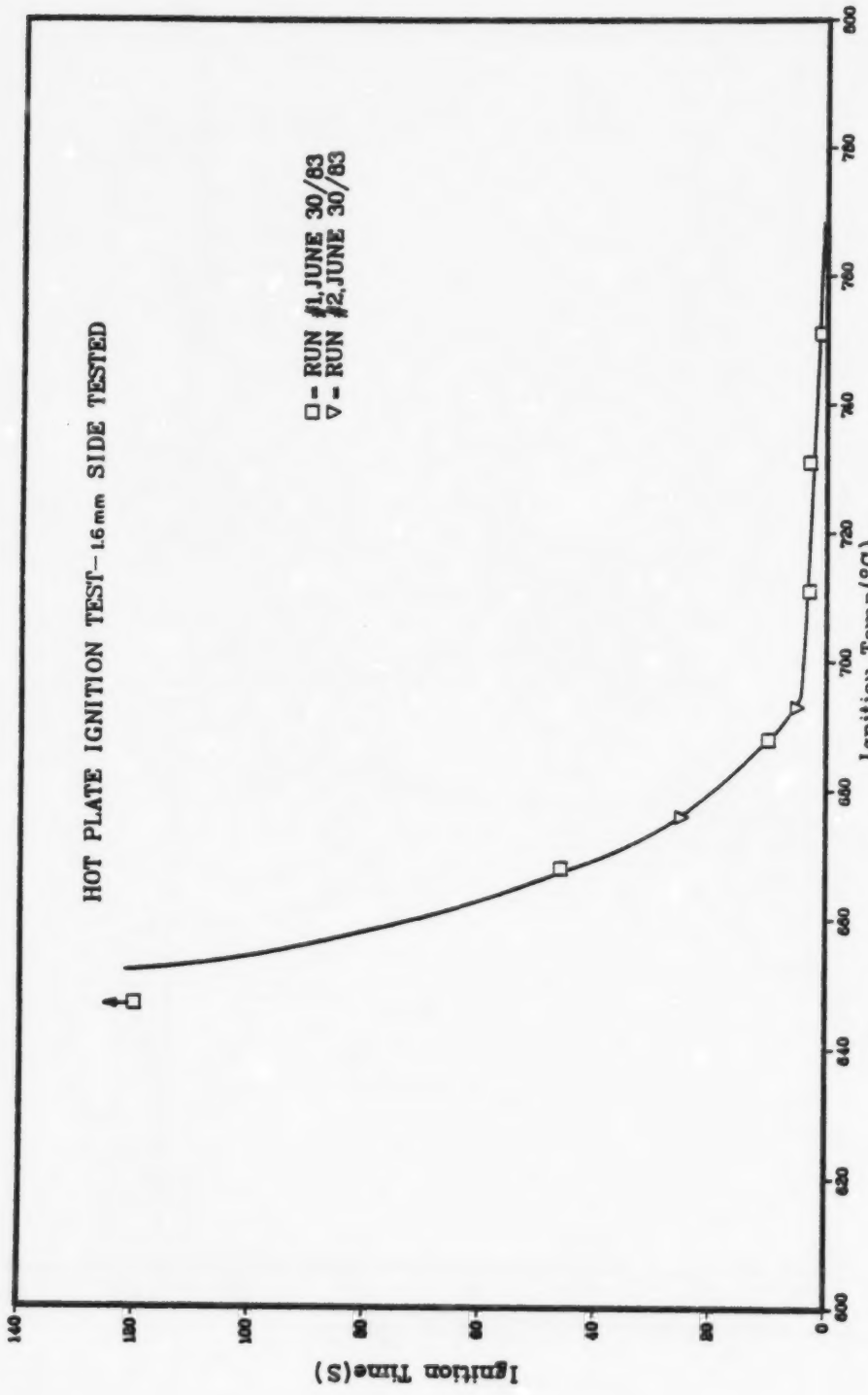

Fig. 13 - 3-ply F.R. - 6.4 x 1.6 mm

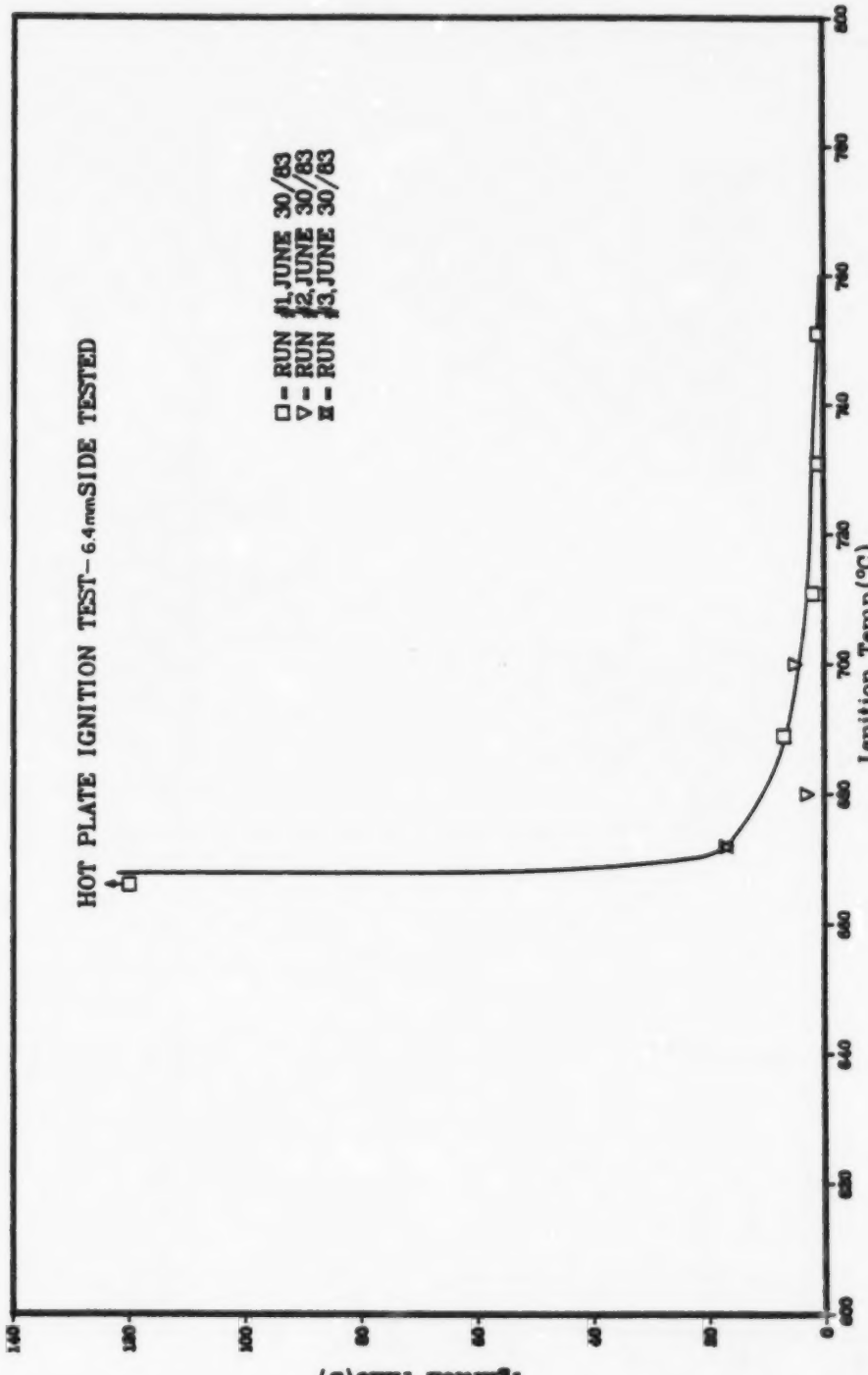

Fig. 14 - 4-ply G.P. - 6.4 x 1.6 mm

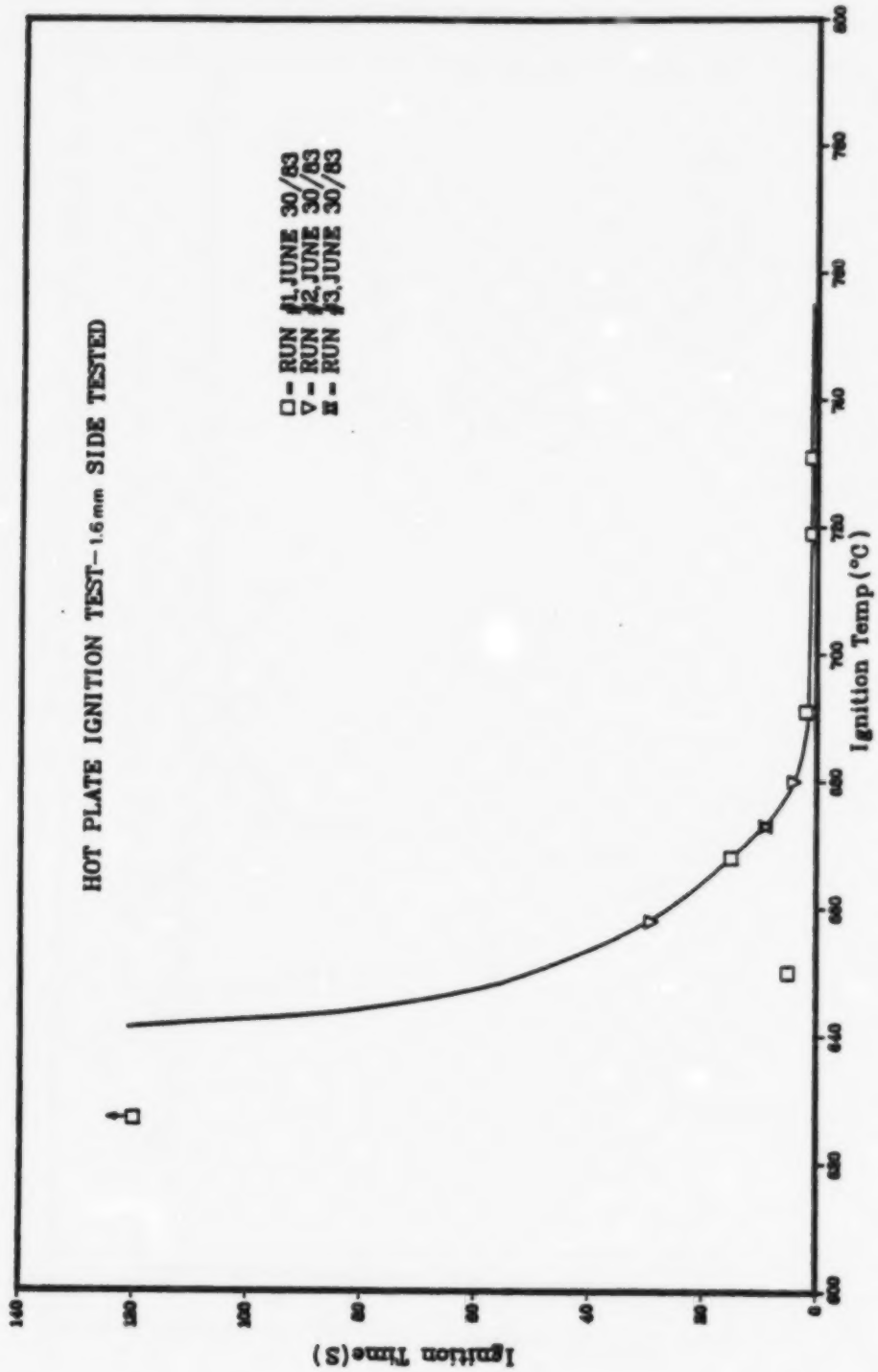

Fig. 15 - 4-ply G.P. - 6.4 x 1.6 mm

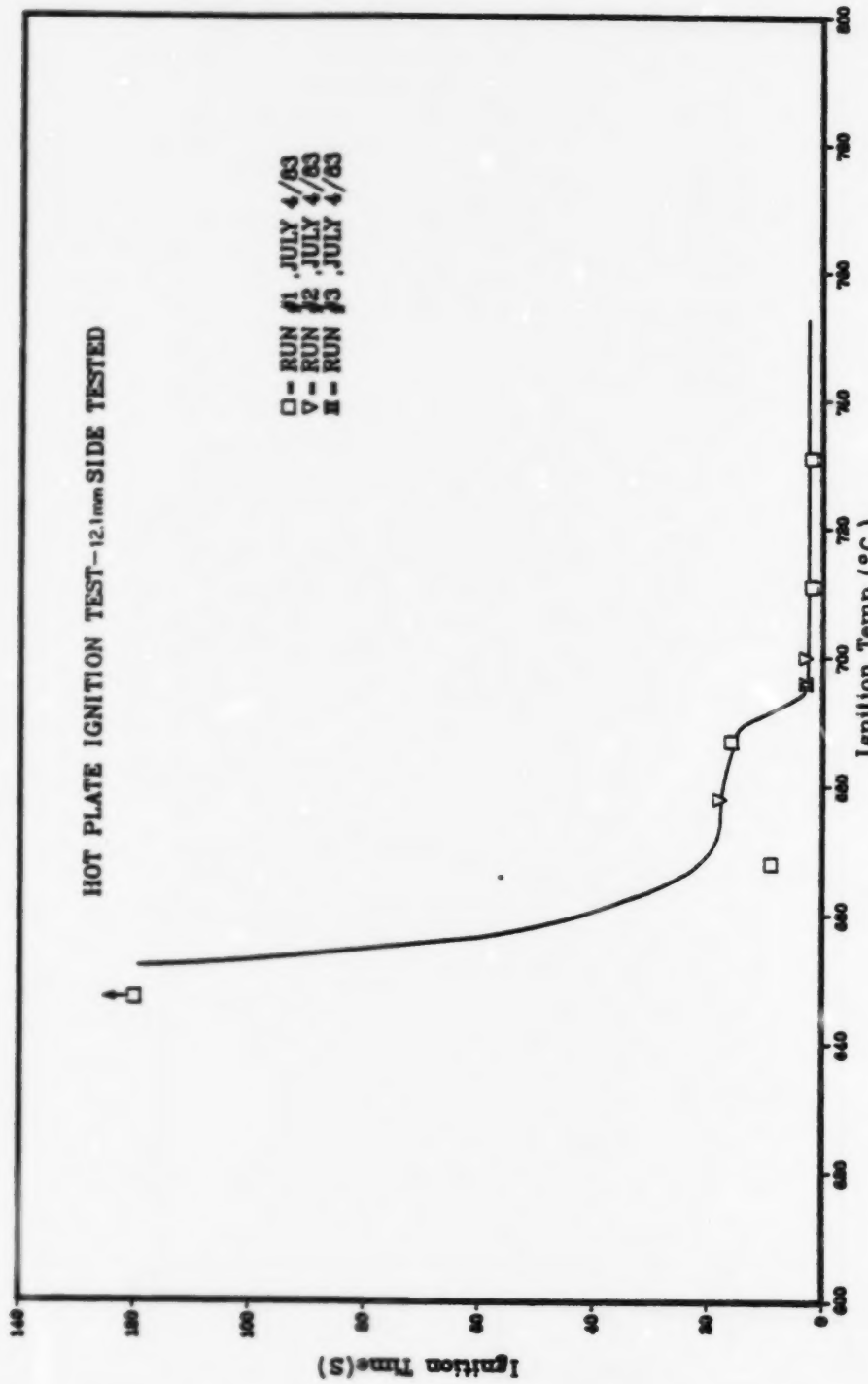

Fig. 16 - 4-ply G.P. - 12.1 x 3.2 mm

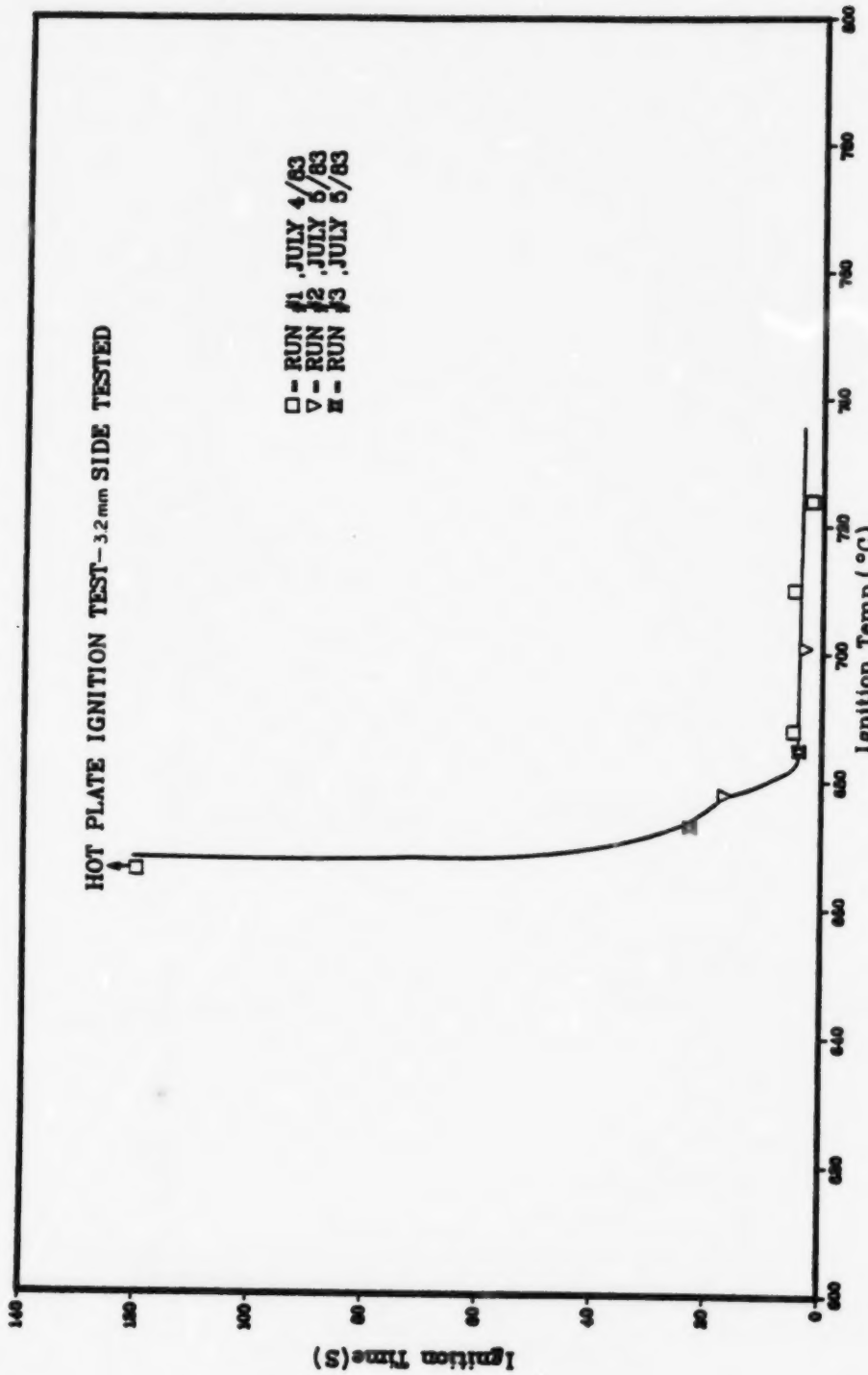

Fig. 17 - 4-ply G.P. 12.1 x 3.2 mm

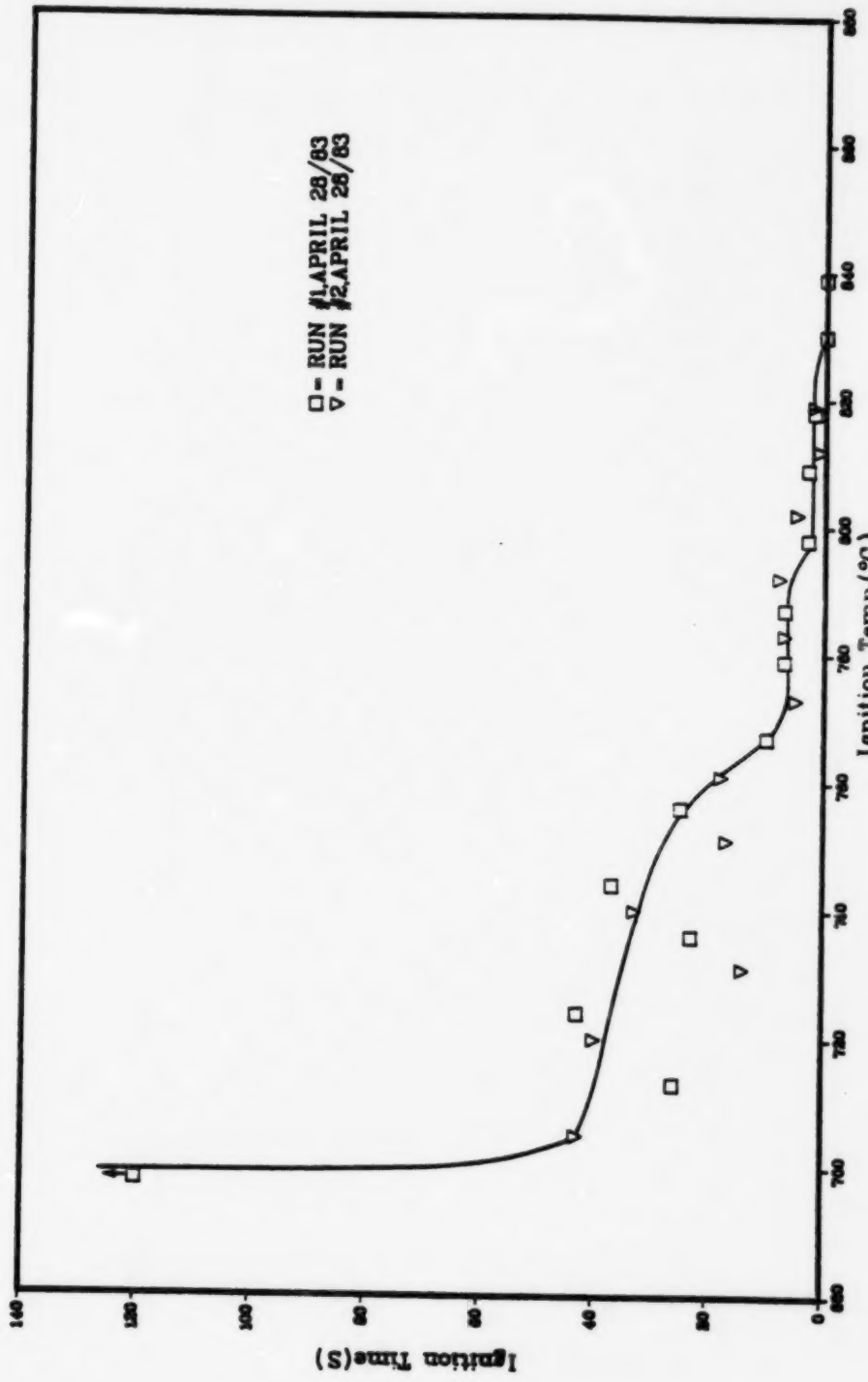

Fig. 18 - PVC - Type A

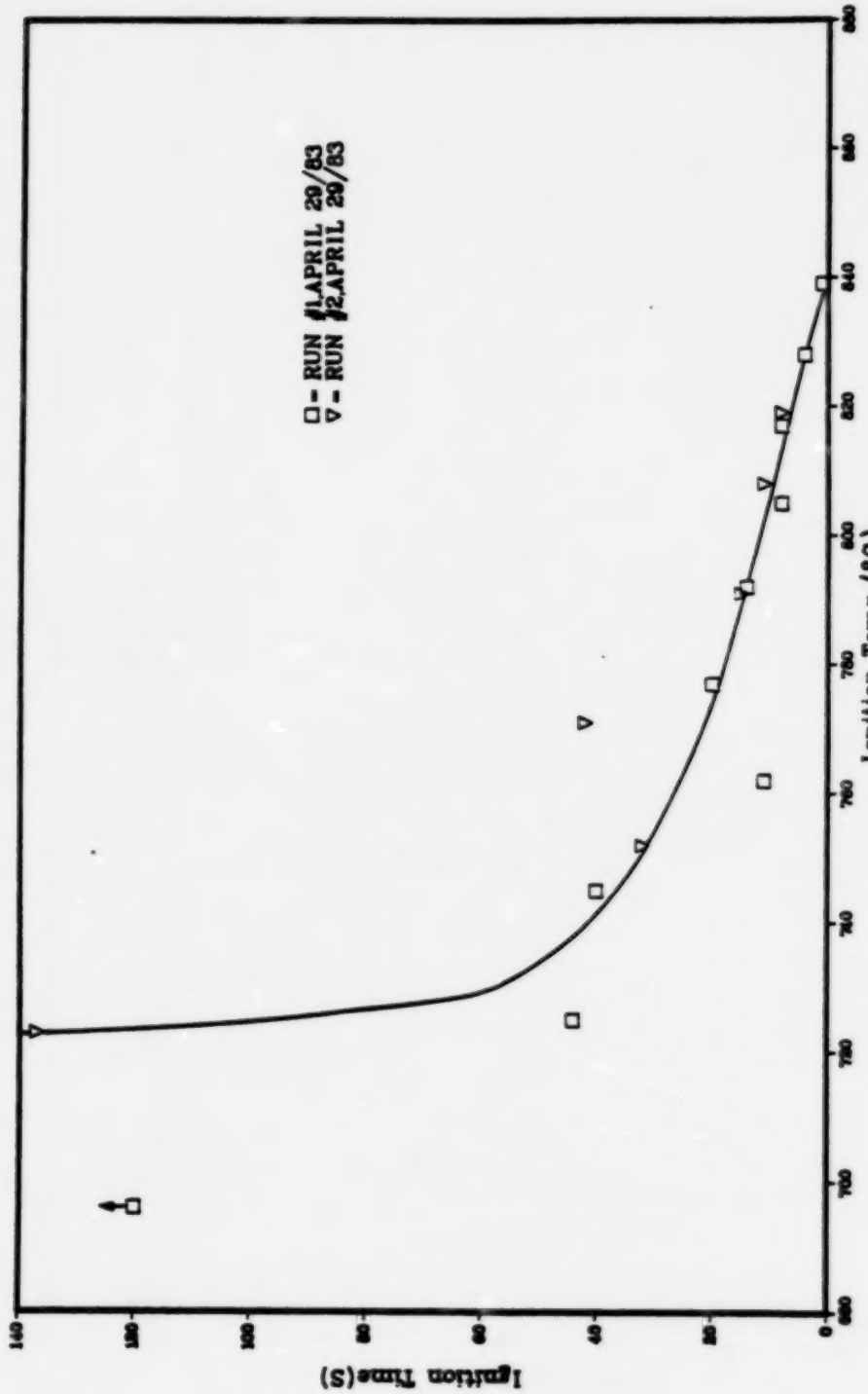

Fig. 19 - PVC - Type B

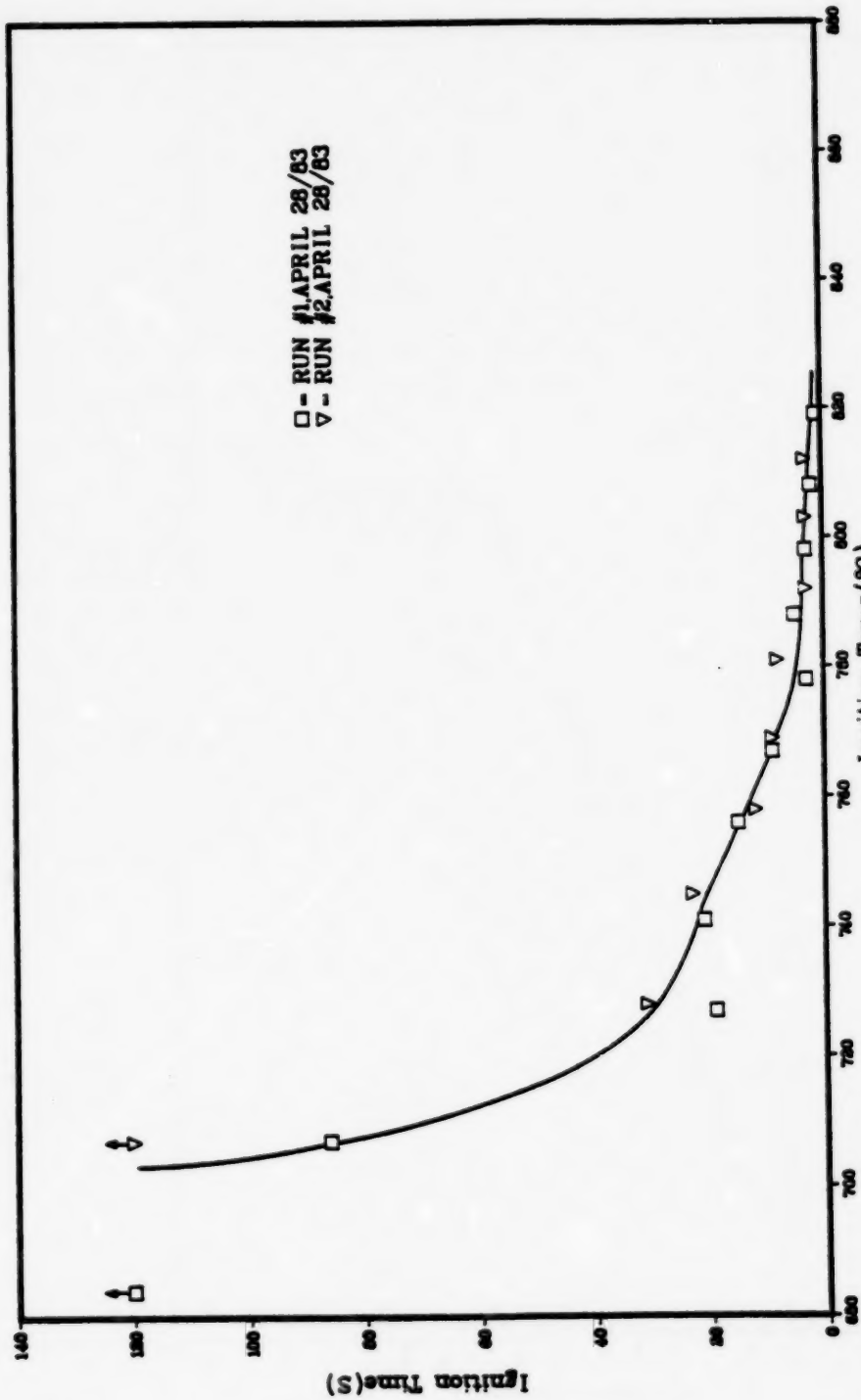

Fig. 20 - PVC - Type C

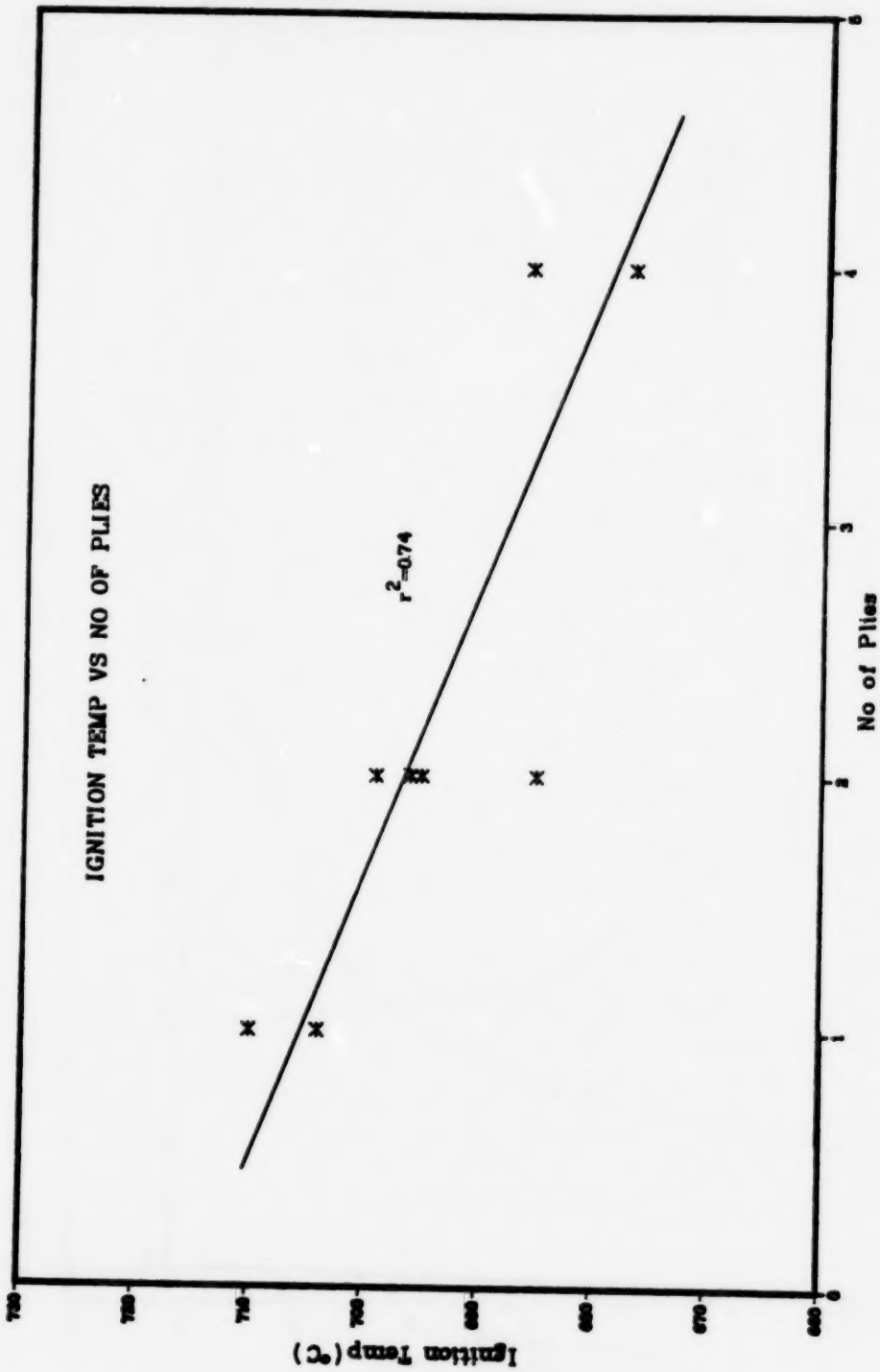

Fig. 21 - Rubber conveyor belts

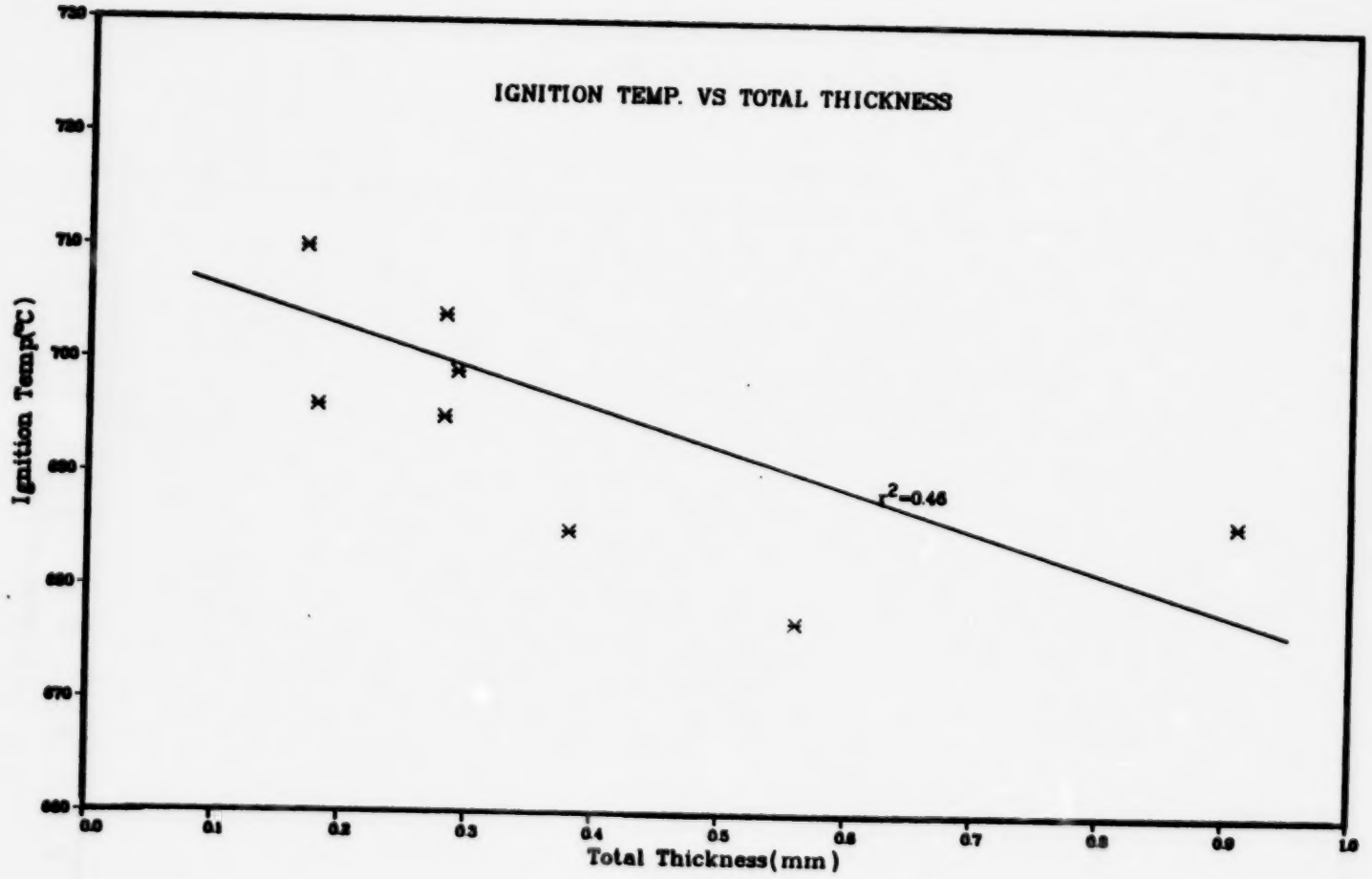

Fig. 22 - Rubber conveyor belts

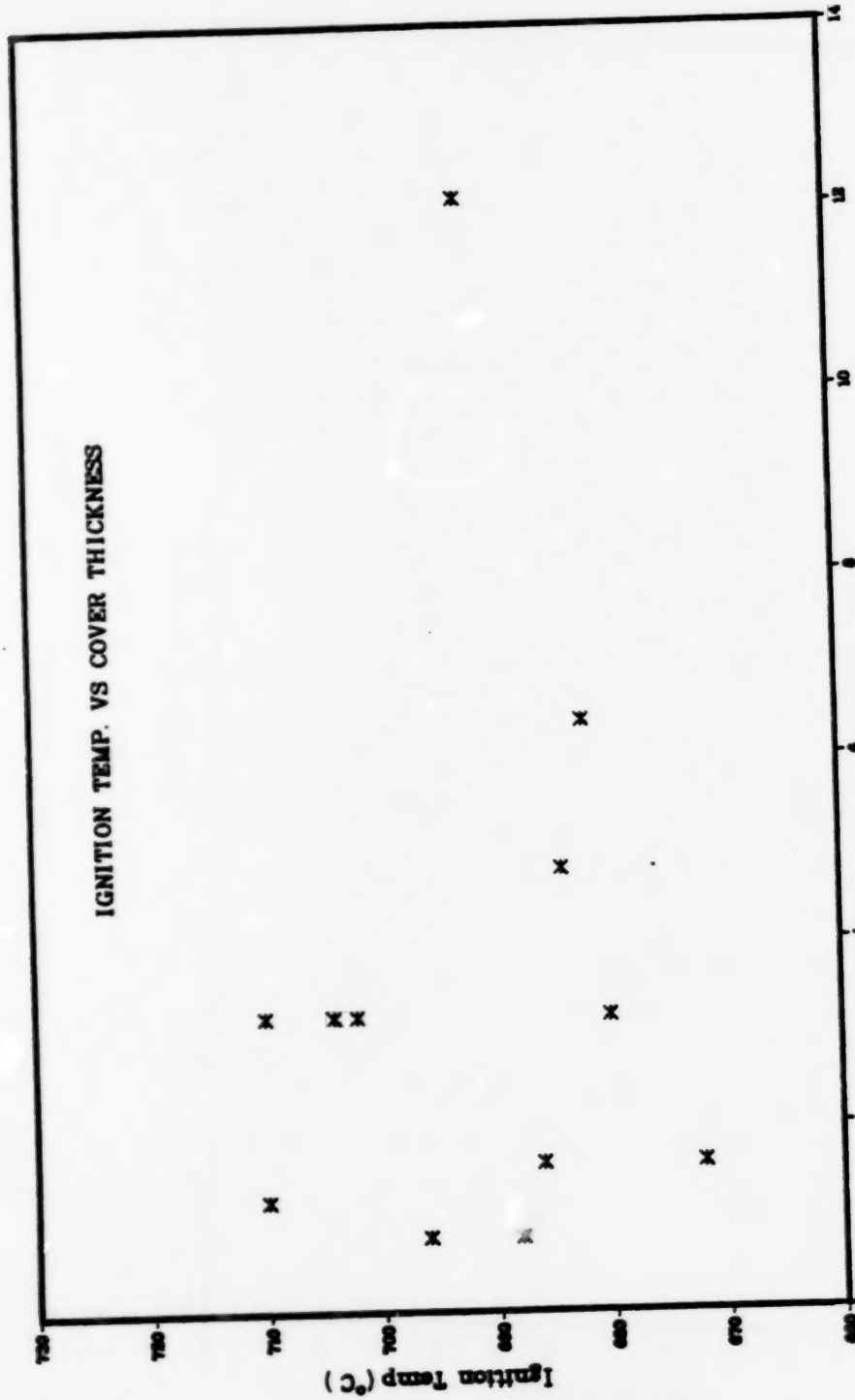

Fig. 23 - Rubber conveyor belts

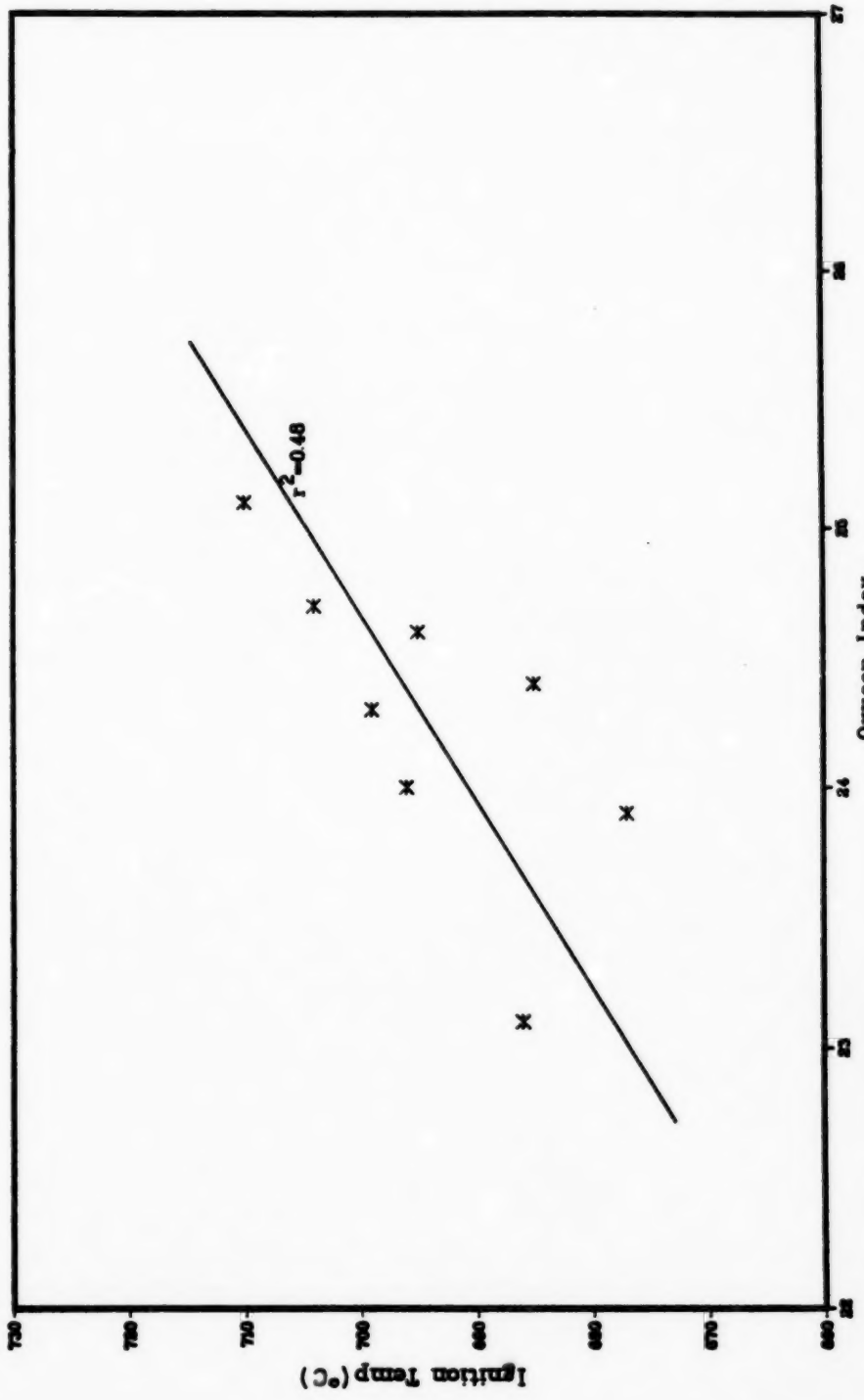

Fig. 24 - Rubber oxygen index vs ignition temp.